MEASURING SPORT-SPECIFIC PHYSICAL ABILITIES IN MALE GYMNASTS: THE MEN'S GYMNASTICS FUNCTIONAL MEASUREMENT TOOL

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ABSTRACT

Purpose/Background: Despite the availability of various field-tests for many competitive sports, a reliable and valid test specifically developed for use in men's gymnastics has not yet been developed. The Men's Gymnastics Functional Measurement Tool (MGFMT) was designed to assess sport-specific physical abilities in male competitive gymnasts. The purpose of this study was to develop the MGFMT by establishing a scoring system for individual test items and to initiate the process of establishing test-retest reliability and construct validity.

Methods: A total of 83 competitive male gymnasts ages 7-18 underwent testing using the MGFMT. Thirty of these subjects underwent re-testing one week later in order to assess test-retest reliability. Construct validity was assessed using a simple regression analysis between total MGFMT scores and the gymnasts' USA-Gymnastics competitive level to calculate the coefficient of determination (r^2). Test-retest reliability was analyzed using Model 1 Intraclass correlation coefficients (ICC). Statistical significance was set at the $p < 0.05$ level.

Results: The relationship between total MGFMT scores and subjects' current USA-Gymnastics competitive level was found to be good ($r^2 = 0.63$). Reliability testing of the MGFMT composite test score showed excellent test-retest reliability over a one-week period (ICC = 0.97). Test-retest reliability of the individual component tests ranged from good to excellent (ICC = 0.75-0.97).

Conclusions: The results of this study provide initial support for the construct validity and test-retest reliability of the MGFMT.

Key Words: Functional measurement, gymnastics, physical abilities

Level of Evidence: Level 3

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INTRODUCTION

Five million young gymnasts, defined as being at least six years of age, participate in formal gymnastics related activities each year in the United States (US).[1] While the vast majority of these young athletes are female, 25% (~ 1.3 million) of the representative gymnastic athletes are young males. Approximately 12,000 of these young male gymnasts compete in the US Junior Olympic program while the remaining primarily participate in activities through the Amateur Athletic Union, the Young Men's Christian Association, and other organizations. In addition to these programs, the number of male gymnasts competing at the high school and collegiate levels in the US is reportedly on the rise.[1]

As opposed to the four events that comprise women's gymnastics, male gymnasts compete in six events: the floor exercise, pommel horse, vault, still rings, parallel bars, and horizontal bar (also known as the high bar). Flexibility,[2-8] speed,[6,9-11] power,[7,8,12,13] strength,[5,6,14,15] muscular endurance,[14] agility,[16] and balance[17,18] have all been associated with competitive gymnastics and may also relate to a gymnast's ability to sustain injury-free and long-term participation in the sport.[8,17,19] As such, it is imperative that coaches, athletic trainers, therapists, and other health care providers be able to objectively measure and monitor an individual gymnast's physical abilities as a means of promoting healthy, injury-free participation in the sport.

Within USA-Gymnastics, a system of competitive levels (ranging from a low of 4 to a high of 10) is used to rank the skills and abilities of individual gymnasts. Moving from one level to the next requires that a gymnast attain a specific all-around score as well as be able to perform specific gymnastics skills that increase in difficulty as the competitive level increases. Each increasing competitive level thus places increased demands on a gymnast in regards to higher levels of technical skill and mental acuity in tandem with increased levels of physical ability (e.g. strength, power, speed, flexibility, balance and agility).[16]

At the forefront of the USA-Gymnastics program is the need to identify talented young gymnasts for both individual and team level competition.[20-25] Screening the available population for the best possible athletes however, has historically been based upon the opinion of "experts" in the sport with very little, if any, consideration of objective metrics.[26] With an increasing push for excellence, national and international stakeholders in the sport have placed an increased emphasis on identifying individuals with the potential to become an elite-level gymnast. For example, through USA-Gymnastics, the US has instituted an extensive talent identification program for male gymnasts called Future Stars.[25] Future Stars is designed exclusively for boys ages 8 to 13 and consists of selected gymnastics skills and compulsory routines plus strength and flexibility evaluations. It is used primarily with club gymnasts to identify competitive potential and to aid in the development of the US competitive gymnastics program and was not designed to assess the gymnastic-specific physical abilities of individual athletes. Future Stars also was not designed to address the needs of gymnasts of all ages or those who compete through high school or collegiate programs. While specialized training is needed to administer the Future Stars program, the reliability and validity of the Future Stars testing procedures have not been reported.

In contrast to screening for talent, field-testing is often used to assess an athlete's sport-related physical abilities.[27-34] Some field-tests focus on a specific aspect of sports function (such as the hop test [35] or the agility T-test[36]) while other tests, such as the Functional Movement Screen™,[37,38] consist of a series of individual items designed to assess an athlete's abilities across multiple aspects of function. Sports-specific field-tests focus on assessing the specific physical abilities and attributes necessary for successful participation in a particular sport.[24,27,29,30,34-36]

Although establishing the reliability and validity of a tool is a multi-dimensional and on-going process, currently there is not a reliable and valid test to evaluate the sport-specific physical abilities needed for competition in men's gymnastics. Grabiner and McKelvain developed a physical fitness testing battery for male gymnasts, but did not report reliability or validity data.[21] The recently developed Gymnastics Functional Measurement Tool (GFMT) has been shown to have good test-retest reliability and construct validity, but, it was only developed for female gymnasts.[39] The Men's Gymnastics Functional Measurement Tool (MGFMT) was thus developed to allow coaches, athletic trainers, and other health professionals to

Table 1. *Individual Items Comprising the Men's Gymnastics Functional Measurement Tool*

Item	Targeted Area(s) of Fitness Assessment	Units of Measure for Raw Score
The Rings Hold Test	Should adductor strength and endurance	Distance (cm) from axilla/arm length (cm)
The Vertical Jump Test	Lower extremity power	Height jumped (cm)
The Hanging Pikes Test	Abdominal strength, hip flexor strength, and flexibility as well as grip strength	Number of repetitions
The Shoulder Flexibility Test	Shoulder complex flexion flexibility	Dowel height (cm) / arm length (cm)
The Agility Test	Speed, endurance, and agility	Seconds
The Overgrip Pull-up Test	Upper extremity strength and muscular endurance	Number of repetitions
The Splits Test	Pelvis and lower extremity flexibility	Sum of L, R, and middle split clearance (cm) / leg length (cm)
The Handstand Push-up Test	Shoulder and upper extremity strength and endurance	Number of repetitions
The Star Excursion Balance Test	Balance and muscular control	Sum of eight distances (cm) / leg length (cm)
The Handstand Test	Strength, endurance and balance	Seconds

measure a gymnast's overall physical abilities while minimizing the impact of gymnastic skill on testing scores.[40,41] The individual test items included in the MGFMT (Table 1) were developed based on a set of criteria including: 1) the test item had to be easy to apply without requiring specialized equipment, 2) the test item had to reflect physical abilities inherent in male gymnastics skills and activities, 3) the test item had to be quantitative, 4) the test item had to measure flexibility, strength, power, agility or balance of one or multiple body segments and 5) the test item would not require a tester to have previous or current skills in gymnastics. All items on the MGFMT thus had to be able to be performed by a non-gymnast. Detailed information regarding administration of each test item is provided in Appendix I.

The purpose of this study was to develop a scoring system for the MGFMT (both for individual test items and for a composite score) and to begin the process of establishing the reliability and validity of the MGFMT.

METHODS

Approval for the study was obtained from the Office for the Protection of Research Subjects at Northwest-ern and Nova Southeastern Universities. Competitive male gymnasts were recruited from five different private gymnastics clubs throughout Illinois and Texas. Inclusion criteria required the subjects to be male, between 7 and 18 years of age, regularly practicing gymnastics three to six days per week, and competing in gymnastics at USA-Gymnastics levels 4 to 10. Exclusion criteria included musculoskeletal pathology currently limiting the gymnast's ability to train or compete; a history of, or current systemic illnesses including cardiovascular or pulmonary disease; musculoskeletal disease or rheumatoid arthritis; and a lack of informed assent given by the subject or consent given by the parent/legal guardian. The total number of gymnasts tested at each competitive level was based on a sample of convenience and thus the number of gymnasts tested at each level varied. A total of 83 subjects participated in the study. Figure 1 offers a flowchart reflecting subjects' participation in the study.

All testing was performed in the subjects' home gyms or in a gym familiar to the subject. Subjects did not have prior knowledge or exposure to the specific items composing the MGFMT. Each subject provided his own USA-Gymnastics competitive level, which
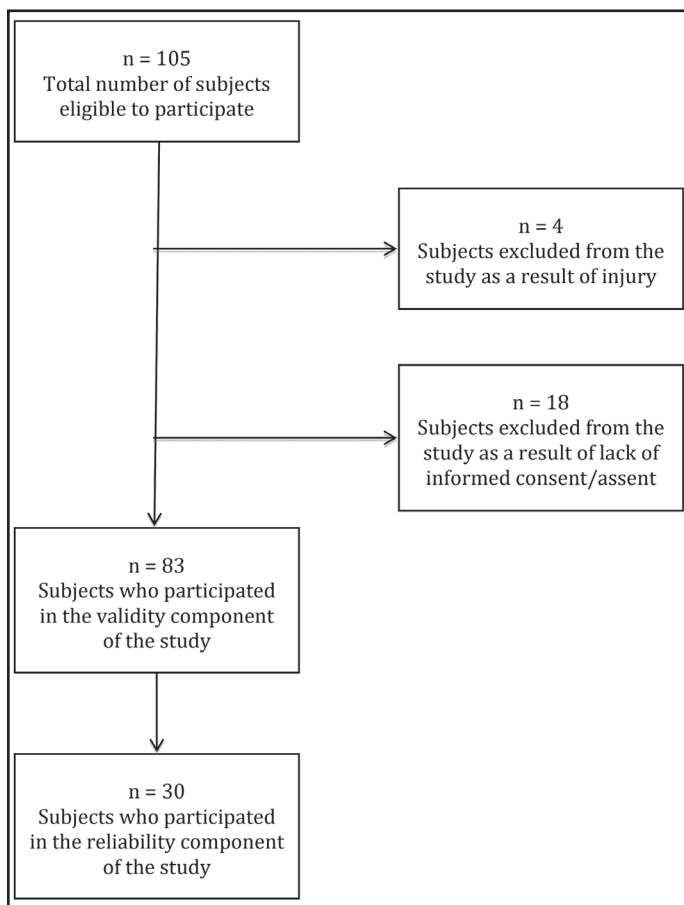
Figure 1. *Flowchart of Subjects' Participation in the Study.*

was recorded by the testers. Prior to testing, subjects completed their regular, coach-directed warm-up routines without regard to the requirements of the MGFMT. Given that field-tests comprised of multiple items are often administered in stations each consisting of an individual item,[40,41] subjects were placed into groups of 5-10 and moved through each of the stations to complete the MGFMT. Data were collected by gymnastics coaches with a minimum of five years of coaching experience, the principal investigator, and another licensed physical therapist with gymnastics experience. In an effort to simulate actual practice patterns, all data collectors were provided with a detailed set of instructions for administering each item on the MGFMT but did not undergo any specialized or extensive training. The principal investigator observed initial data collection to confirm testing was done correctly. Raw data for each item of the MGFMT was recorded in units of measurement that were appropriate for the activity.

Units of measurement for the raw data for each test item are listed in Table 1. Subjects were not intentionally masked as to their item scores. Individual MGFMT items were completed in the following order to help reduce the possible effects of regional fatigue: Hanging Pikes Test, Rings Hold Test, Vertical Jump Test, Shoulder Flexibility Test, Handstand Pushups Tests, Agility Test, Star Excursion Balance Test, Handstand Hold Test, Overgrip Pull-ups Test, and the Splits Test. Subjects were given a minimum of five and a maximum of 15 minutes rest between administrations of each item of the MGFMT.

From the 83 total subjects, a random convenience sample of 30 subjects from two gymnastics clubs in Illinois was chosen to participate in test-retest reliability testing. These 30 subjects were retested with the MGFMT one week after initial testing. Testing conditions and administration were consistent between the two administrations of the MGFMT including warm-up and item administration order. To help ensure that test-retest reliability rather than intra-rater reliability was assessed, testers administered different items from the MGFMT on each of the two administration dates.

Statistical Methods

Development of the Scoring System
The scoring system for the MGFMT was developed utilizing the same method used to develop the scoring system for the GFMT. Raw test item scores in the appropriate units of measurement were recorded for each of the individual test items. These raw scores were used to calculate the range, mean, and standard deviation for each individual item of the MGFMT (n = 83). Data was then transformed to an ordinal scale. In an attempt to reduce the possibility of ceiling and floor effects, five percent of the total range of the raw scores was added to the high score of each item and five percent was subtracted from the low score of each item. The resulting range of scores for each individual item was then divided by 11 to create a 0 to 10 ordinal scale for each individual item on the MGFMT.[39] The ordinal scale for each item was used to create a total MGFMT score out of a possible 100 points (10 points for each item). Based on these findings, the scoring for each individual item and for the total MGFMT score were finalized and

are provided in the MGFMT Score Sheet found in Appendix II.

Test-retest and Construct Validity

Test-retest reliability was analyzed using Model 1 Intra-class correlation coefficients (ICC).[42] Although a process of systematic randomization was not employed in the study, a Model 1 ICC was used to reflect the concept that individual items on the MGFMT were administered on each of the two test dates. The variance assessed was thus restricted to differences in the subjects' scores in the test-retest design and necessitated the use of a Model 1 ICC. Values for the ICC were interpreted according to these levels of agreement: 'poor to moderate' = 0.00-0.75, 'good' = 0.75-0.90 and 'excellent' = 0.90-1.00.[42,43] In an effort to better graphically represent the test re-test reliability, comparisons of agreement between test day one and test day two were analyzed using a Lin's Concordance Correlation (LCC) Coefficient (p_c). Ranging between 1 (perfect agreement) and -1 (perfect inverse agreement), p_c represents the extent to which the compared data deviate significantly from perfect concordance.[44]

Given previously reported positive relationships between various singular physical abilities and a gymnast's level of competition with the GFMT,[10,14,21,39] it was theorized that the total scores on the MGFMT would vary with a gymnast's current competitive level. This was based upon the concept that at each increasing competitive level, a gymnast is required to perform increasingly difficult skills that theoretically would require a related increase in the gymnast's physical abilities. In addition, the competitive level of female gymnasts was used in the construct validation process for the GFMT developed for use with female gymnasts.[39] Construct validity was thus evaluated based on the relationship between a gymnast's physical abilities as measured by the MGFMT and the gymnast's current level of competition as reflected by the gymnast's USA-Gymnastics competitive level. A linear regression analysis was performed using a gymnast's USA- Gymnastics competitive level to predict total MGFMT score. The coefficient of determination (r^2) was used to explore this relationship. Statistical significance was set at α = 0.05 level.

RESULTS

Of the 105 subjects assessed for eligibility in this study, 83 participated. Twenty-two of the recruited subjects were excluded from the study due to recent injury (n = 4) or the lack of a signed informed consent or assent (n = 18). The number of subjects representing each competitive level ranged from 6-20. The mean age of participating subjects was 11.07 (range – 7-18) years with these subjects reporting participation in competitive gymnastics for a mean of 4.36 (range 1-13) years. The mean reported number of hours spent practicing was 8.5 for level 4 gymnasts and 21.4 for level 10 gymnasts. Subject demographics, categorized by USA-Gymnastics competition level, are summarized in Table 2. Mean MGFMT component test item raw scores and standard deviations are presented in Table 3.

Raw scores for all items on the MGFMT demonstrated a normal distribution (skewness = [-]0.56 – [+]1.51). The relationship between the individual component test item raw scores of the MGFMT as well as with the MGFMT total-score and subjects' current USA-Gymnastics competitive level was evaluated and can be seen in Table 4. Several of the relationships between the individual component raw scores were statistically significant, however, r^2 values revealed poor to good relationships between USA-Gymnastics competitive level and individual component raw scores (r^2 = 0.004-0.64). The relationship between MGFMT total-scores (out of a possible score of 100) and the subjects' current USA-Gymnastics competitive level was found to be good (r^2 = 0.63) and can be observed graphically in Figures 2 and 3. To rule out alternative explanations for the relationship between USA-Gymnastics competitive level and MGFMT total-scores, the relationships between MGFMT total-scores and age, MGFMT total-scores and bodyweight as well as MGFMT total-score and hours of training per week were also explored. Statistically significant relationships were identified between MGFMT total-score and age (r^2 = 0.48), between MGFMT total-score and bodyweight (r^2 = 0.30) and between MGFMT total-score and hours of training per week (r^2 = 0.56).

Raw item scores were used to examine the test-retest reliability for each item on the MGFMT. Test-retest reliability of total MGFMT scores was also deter-

Table 2. *Subject Demographics by USA-Gymnastics Competitive Level*

Competition Level	4	5	6	7	8	9	10	All Subjects
Number of Subjects	20	12	20	7	8	6	10	83
Mean Age in Years (sd)	8.3 (1.3)	9.2 (1.3)	10.6 (1.6)	12.3 (0.8)	13.3 (1.7)	12.8 (0.8)	16.2 (1.1)	11.1 (2.9)
Mean Years Competing	1.4	2.7	4.4	5.14	5.7	6.7	9.5	4.4 (2.9)
Mean Reported Number of Hours Practicing per Week	8.5	10.7	14.5	20.8	17.7	18.7	21.4	14.5 (5.4)
Mean Height in cm (sd)	129 (9.9)	135 (9.3)	142 (12.8)	149 (7.6)	154 (15.4)	149 (4.9)	163.8 (3.8)	142.8 (15.0)
Mean Weight in kg (sd)	28.2 (6.4)	29.7 (6.1)	35.1 (8.1)	39.5 (4.8)	48.8 (14.9)	43.1 (5.3)	56.6 (4.2)	82.9 (26.5)
sd= Standard Deviation, cm = Centimeters, kg = Kilograms								

Table 3. *Mean and Standard Deviation of MGFMT Individual Item Scores and Total Men's Gymnastics Functional Measurement Tool Scores (n = 83)*

	Splits Test (combined [cm/leg length]) Mean (sd)	Shoulder Flexibility Test (cm/arm length) Mean (sd)	Hanging Pikes Test (reps) Mean (sd)	Overgrip Pull-ups Test (reps) Mean (sd)	Handstand Push-up Test (reps) Mean (sd)	Rings Hold (Cm from axilla/cm arm length) Mean (sd)	Agility Test (secs) Mean (sd)	Vertical Jump Test (cm) Mean (sd)	Star Excursion Balance Test (total distance/ leg length *100) Mean (sd)	Handstand Hold Test (secs) Mean (sd)	Total MGFMT Score
Total sample (Levels 4-10)	0.55 (0.35)	0.55 (0.19)	17.8 (10.3)	9.2 (5.5)	6.8 (7.2)	0.39 (0.13)	19.84 (2.1)	40.4 (11.3)	767 (89.5)	34.5 (35.5)	42.4 (14.9)
Level 4 scores	0.62 (0.28)	0.46 (0.16)	11.4 (6.8)	4.2 (4.3)	3.0 (4.3)	0.28 (0.1)	22.13 (1.8)	29.6 (6.4)	696 (109)	7.7 (14.6)	25.2 (8.0)
Level 5 scores	0.54 (0.17)	0.56 (0.12)	13.9 (7.1)	6.8 (2.2)	4.17 (3.3)	0.38 (0.11)	20.5 (1.3)	34.6 (6.6)	777 (70.9)	19.7 (19.4)	36.7 (7.1)
Level 6 scores	0.49 (0.32)	0.61 (0.22)	15.8 (9.0)	8.6 (3.6)	7.10 (7.4)	0.35 (0.07)	19.9 (1.2)	38.0 (6.8)	793 (53.9)	29.9 (28.7)	41.9 (9.6)
Level 7 scores	0.23 (0.7)	0.67 (0.31)	20.9 (11.4)	12.0 (3.3)	6.29 (5.9)	0.54 (0.07)	18.9 (1.53)	48.9 (8.4)	815 (82.2)	46.6 (47.0)	57.5 (9.5)
Level 8 scores	0.62 (0.21)	0.61 (0.11)	25.1 (8.1)	12.9 (5.6)	6.75 (5.2)	0.44 (0.12)	18.1 (0.7)	46.8 (8.3)	777 (90.4)	37.8 (30.9)	50.2 (7.6)
Level 9 scores	0.42 (0.22)	0.64 (0.11)	27.2 (9.1)	13.3 (4.0)	9.5 (9.1)	0.46 (0.11)	17.8 (1.1)	49.0 (5.2)	759 (75.1)	76.0 (32.0)	56.7 (10.1)
Level 10 scores	0.80 (0.38)	0.45 (0.11)	25.4 (12.7)	15.9 (4.1)	15.7 (8.8)	0.54 (0.15)	17.7 (1.3)	57.5 (5.5)	809 (70.5)	78.7 (26.6)	60.8 (8.7)
sd= Standard Deviation, cm = Centimeters, kg = Kilograms, secs = Seconds, deg = Degrees, reps = Repetitions,											

mined. Reliability testing of the MGFMT total score showed good test-retest reliability over a one-week period (ICC = 0.97). Test-retest reliability coefficients are shown in Table 5. A statistically significant differ- ence (p < 0.05) between the first and second test scores was identified for the MGFMT Total score and for the following test items: Hanging Pikes Test, Agility Test, Vertical Jump Test, Start Excursion Balance Test. Test-

Table 4. *Relationship between Men's Gymnastics Functional Measurement Tool (MGFMT) Individual Item Raw Score and Total MGFMT Score and the Subjects' Current USA-Gymnastics Competitive Level, Age, and Body Weight (n = 83)*

	Splits Test	Shoulder Flexibility Test	Hanging Pikes Test	Overgrip Pull-ups Test	Handstand Push-up Test	Rings Hold Test	Agility Test	Vertical Jump Test	Star Excursion Balance Test	Handstand Hold Test	Total MGFMT Score
Test score vs. Competitive Level	0.004	0.01	0.29*	0.51*	0.24*	0.36*	0.55*	0.64*	0.10*	0.44*	0.63*
Test score vs. Hours of Training per Week	0.003	0.02	0.21*	0.43*	0.26*	0.313*	0.36*	0.49*	0.07*	0.38*	0.56*
Test score vs. Age	0.004	0.002	0.12*	0.42*	0.41*	0.16*	0.51*	0.61*	0.07*	0.26*	0.48*
Test score vs. Body Weight (kg)	0.03	0.001	0.05*	0.25*	0.06*	0.35*	0.47*	0.57*	0.04	0.17*	0.30*

Values expressed in terms of Coefficient of Determination (r^2)
* Denotes statistically significant relationship ($p<.05$)
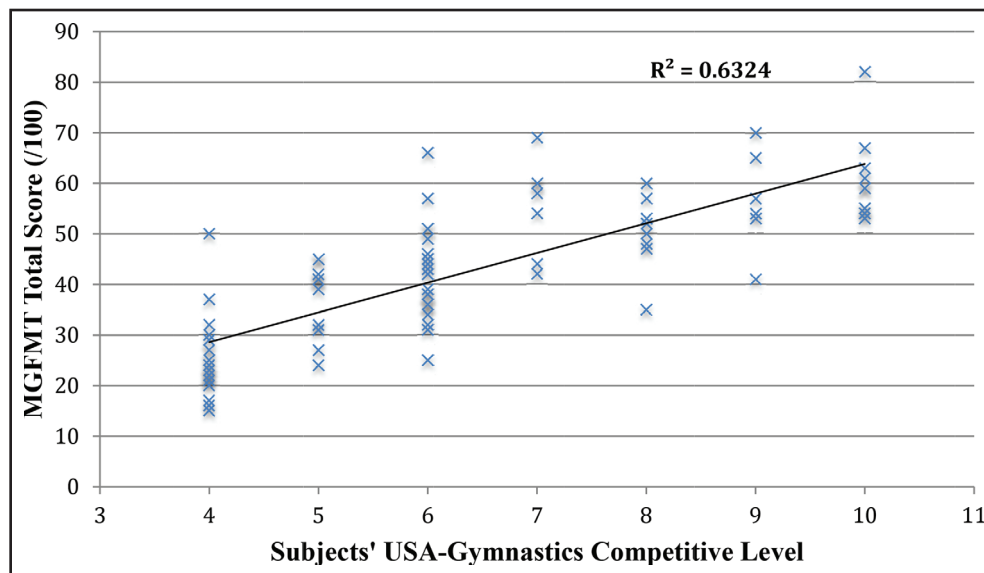
Figure 2. *The Relationship between the Men's Gymnastics Functional Measurement Tool (MGFMT) Total Score and Subjects' USA-Gymnastics Competitive Level.*

retest reliability of the individual component items was good (ICC = 0.70-0.92). Test-retest reliability testing of the MGFMT total-score showed excellent test-retest reliability over a one-week period (ICC = 0.97).

DISCUSSION
The MGFMT is a functional tool designed to assess the unique physical abilities that are necessary for participation in men's gymnastics. The procedures and methods used in this study allowed the researchers to evaluate the MGFMT within the context of its intended use as a field test to assess sport-specific physical performance characteristics of male gymnasts.[40,41] As such, testing was conducted in a manner consistent with the sport in an environment familiar to the individual athletes. Given that the MGFMT
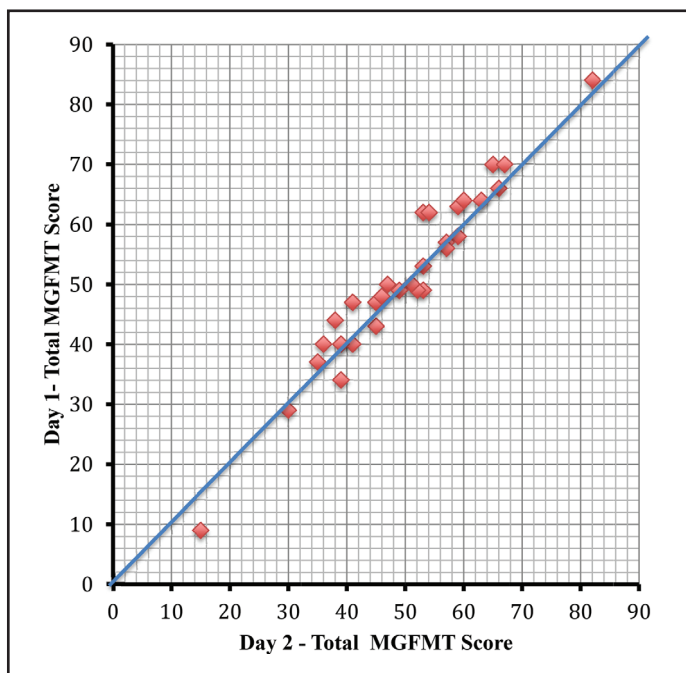
Figure 3. *Lin Concordance Coefficient Correlation for Test-retest Reliability of the Men's Gymnastics Functional Measurement Tool (MGFMT) Total Score*

can be administered without extensive training using equipment readily available in a gymnastics gym, the authors believe that the MGFMT can be easily incorporated into any gymnastics program.

An improved ability to accurately measure strength, power, speed, balance, flexibility, and agility may assist in identifying and remediating deficits in the physical performance characteristics needed by

male competitive gymnasts.[17] In his comprehensive analysis, Sands[19] suggested that a gymnast routinely and repeatedly performs difficult skills but may not possess the overall physical abilities and fitness levels necessary for prolonged, successful participation in the sport.[11] In competitive gymnastics, an annual injury rate as high as 294% in male and female club gymnasts in the United States has been reported.[45-47] Using the MGFMT to identify deficits in sport-specific physical abilities that can be targeted as part of a gymnast's individual training regime may prove useful in injury prevention. Future studies should explore use of the MGFMT to identify and remediate injury risk in male gymnasts.

The results of this study provide initial support for the construct validity and test-retest reliability of the MGFMT. Although construct validity is only one of the many forms of validity to be considered when evaluating a measurement tool,[42,48] the relationship between a gymnast's total MGFMT score and current USA-Gymnastics competitive level provides support for the concept that like the GFMT, MGFMT scores will vary based on a gymnast's current competitive level. Examining data from the individual items comprising the MGFMT reveals that certain physical attributes such as power appear to relate more strongly to a gymnast's current competitive level than flexibility. Despite the variations in the strength of the relationship between individual items and competitive level, the authors believe that to completely assess a gymnast's physical abili-

Table 5. *Score Means and Standard Deviations for Both Test Days and Intraclass Correlation Coefficients for Test Retest Reliability (n = 30)*

	Splits Test (combined [cm/leg length]) Mean (sd)	Shoulder Flexibility Test (cm/arm length) Mean (sd)	Hanging Pikes Test (reps) Mean (sd)	Overgrip Pull-ups Test (reps) Mean (sd)	Handstand Push-up Test (reps) Mean (sd)	Rings Hold (Cm from axilla/ cm arm length) Mean (sd)	Agility Test (secs) Mean (sd)	Vertical Jump Test (cm) Mean (sd)	Star Excursion Balance Test (total distance/ leg length *100) Mean (sd)	Handstand Hold Test (secs) Mean (sd)	Total MGFMT 10-test Score (/100) Mean (sd)
Test Day 1 scores	0.60 (0.33)	0.58 (0.17)	22.53 (8.7)	11.5 (5.7)	9.93 (9.1)	0.42 (0.13)	18.8 (1.91)	46.9 (10.3)	780 (80.3)	46.89 (36.9)	49.9 (13.2)
Test Day 2 scores	0.59 (0.32)	0.58 (0.15)	23.27* (9.6)	11.1 (6.1)	9.10 (9.0)	0.46* (0.12)	19.1* (2.18)	50* (12.3)	810* (82.1)	47.0 (41.4)	51.1* (14.5)
Test re-test reliability ICC **	0.97	0.90	0.83	0.89	0.96	0.75	0.95	0.91	0.77	0.91	0.97

- * Signifies statistically significant difference from Test Day 1 scores (p<0.05)
- ** All reliability ICC scores were statistically significant (p<0.001)

ties across multiple domain areas (strength, flexibility, power, etc.), all items on the MGFMT must be administered. Maintaining the complete representation of gymnastics specific physical abilities within the MGFMT is necessary in order to adequately identify a gymnast's deficits in physical abilities and may aid in the development of a program tailored to address individual needs.

This study was limited by several factors. The total number of participants at any given USA-Gymnastics competitive level ranged from 9 to 21. Increasing the number of participants at each USA-Gymnastics competitive level may have yielded different results. While attempts were made in the test-retest procedures to decrease the possibility of a practice or learning effect, the authors' recognize that such factors may have impacted score differences between the first and second administrations of the MGFMT. In addition, the participants included in the study were from a limited number of gymnastics clubs in two specific States: Illinois and Texas. The outcomes of this research also may have been impacted by the training practices routinely performed in these two geographic areas.

Further research is needed to continue the process of establishing the various types of reliability and validity of the MGFMT. Future studies should also explore the ability of the MGFMT total score and individual item scores to identify a gymnast's risk for specific injuries and whether the MGFMT could be used to help determine if and when an injured gymnast can safely resume high-level training and competition.

CONCLUSION

While it is well understood that participation in the sport of gymnastics exposes the athlete to a significant risk of injury, there appears to be a direct relationship between the competitive level at which a gymnast competes and the occurrence as well as the type of injury that is most likely to occur.[45,49] However, attempting to reduce the injury rate in competitive men's gymnastics is a very complex multifaceted endeavor. The establishment of a gymnastics-specific field test, which assesses the physical abilities of male gymnasts, is a first step in a myriad of possible solutions. The information gained through use

of the MGFMT may assist coaches and healthcare providers in identifying and subsequently improving the physical abilities of competitive male gymnasts across the globe.
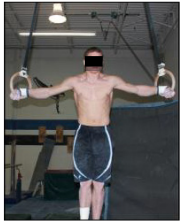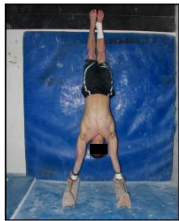
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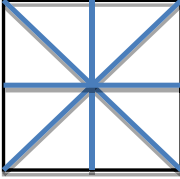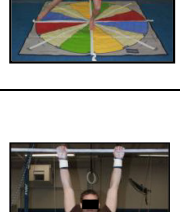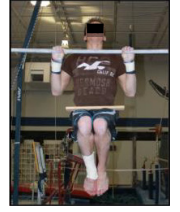
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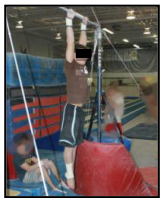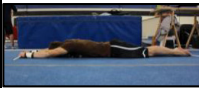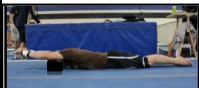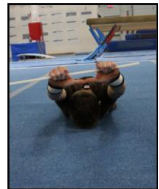
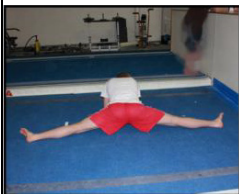|	BRIEF DESCRIPTION	

Rings Hold Test	• Prior to the start to testing both of the gymnast's arms are measured from acromion process to the proximal 2nd digit and recorded in cm.
	   o Arm length will be averaged.
	• Marks are made every 5 cm for the length of each arm starting at the pectoralis fold and progressing distally.
	• The gymnast start in a position with the arms through a pair of still rings located at the axilla.
	   o The rings must be placed at a height where the gymnast can bend his knees and hang by the rings
	• The subject lifts his legs off the floor and should be suspended by the rings for 5 seconds with his shoulders abducted to 90 degrees and elbows straight.
	• If five sends suspension is completed, the rings are moved to the next mark (5 cm distal) and the subject will again lift his legs and hang with his shoulders abducted to 90 degrees and elbows extended.
	• The process is continued until the gymnast is unable to support his bodyweight in the required position for 5 seconds.
	• The test will be terminated if the gymnast is unable to support himself for the required 5 seconds or if he breaks the 90-degree shoulder abduction or elbow extension form.
	• A measurement will be than taken from the mark at which the last completed ring hang was completed and the acromion process.
	
	➢ Raw test score is the distance of the last successfully completed hang divided by the length of the gymnasts arms	

Handstand Pushup Test	• The gymnast starts in a handstand position on parallels spaced with his hands shoulder width apart and 6-12 inches from the wall.
	   o The gymnast's feet should be touching the wall so balance is not needed.
	• The handstand push-up is then performed with the body in a straight, vertical position.
	• The gymnast will lower himself until he touches his head to the floor.
	• Following the head-to-floor contact, the gymnast must extend the elbows until they are locked.
	• The gymnast should perform as many handstand push-ups as possible.
	   o The Push-up does not count if the gymnast fails to reach the floor with his head, if he does not fully extend his elbows, or if his feet leave the wall and touch the floor; however, the test can still proceed.
	
	➢ The test score is based on the total number of properly completed handstand push-ups.	

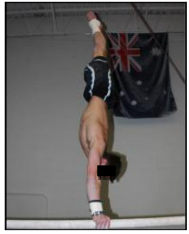|	
Star Excursion Balance Test	• The subject's dominant leg should be identified. • The length of the gymnast's lower extremity is measured from the anterior superior iliac spine to the medial malleolus and recorded. • Subjects should carry out the testing barefoot or in gymnastics slippers. • The dominant foot/stance foot should be placed aligning the heel with the center of a grid and the great toe with the anteriorly projected line of the grid. (Grid depicted at the right should measure 2.2X2.2 meters) • The subjects are asked to maintain a single-leg stance on the stance leg while reaching with the opposite lower extremity to toe-touch as far as possible along the chosen grid line. ○ The foot is only allowed to touch lightly so as not to aid balance. • The subject then returns to bilateral stance. • The point at which the subject touched is marked by the examiner and measured manually using a measuring tape. • This process is carried out on all eight of the grid-lines. • The distances of all eight reaches were then added. ➢ Test score is based on the sum of eight distances reached and divided by the length of the gymnast's leg.	

Overgrip Pull-ups Test	• The gymnast performs pull-ups starting in a hanging position from the standard horizontal bar with an over grip and hips and knees flexed to 90 degrees.
	  ○ Handgrips will not be used.
	  ○ A piece of wood (16x1x4 in) will be placed on the thighs at hip level to eliminate the aid of momentum in the completion of the pull-up.
	• The gymnast is to complete as many pull-ups as possible while maintaining the starting lower extremity position.
	• A pull-up cycle will start in the full hanging position (elbows extended) and raising the chin so that it clears the plane of the horizontal bar completely.
	• The gymnast will then lower his body in a controlled fashion until his elbows are extended to complete the cycle.
	• A pull-up will not count if the chin does not clear the bar, if the gymnast does not start with the elbows fully extended, or if the block of wood falls from the thighs.
	• The test can continue as long as the grip is maintained.
	• The test will terminate after 3 unsuccessful attempts or at the request of the gymnast due to fatigue or other reasons
	
	➢ The raw test score will be the number of Pull-up cycles completed.	

Vertical Jump Test	• Before the Jump Test, the gymnast places a generous amount of chalk on his fingers so that accurate measurements can be made. • The gymnast stands with his dominant side to the wall (but not against it) and perform a vertical jump using both legs, placing a chalk mark on the wall at the top of his jump. • The jump must be performed by pushing off from both lower extremities equally. • Following the jump, standing flat-footed with the dominant side to the wall, the gymnast reaches with the chalked hand directly overhead, touching the wall and leaving a mark of chalk at the highest point. • Using a tape measure, the examiner measures and records the distance between the tops of the two chalk marks in a line perpendicular to the floor to the nearest centimeter. ➢ The raw test score is total height jumped
Hanging Pikes	• The gymnast begins the test from a dead hang, without the use of handgrips, on a standard horizontal bar. • The gymnast is then asked to flex at the hips with legs together and knees extended and attempt to touch his toes to the bar. • Between pike attempts, the gymnasts must be in a momentary dead hang to prevent the use of momentum to gain an advantage for his next pike-up. ➢ The raw test score is the number of pikes completed.
Shoulder Flexibility Test	• Prior to shoulder flexibility testing, the gymnast's arm length is measured from the tip of the acromion process to a ½ inch wooden dowel grasped by both hands while holding his shoulders flexed to 90 degrees. • For testing, the gymnast lies prone on a firm floor with his chin and nose touching the floor. • Both arms are held parallel to the body with the shoulders flexed to 180 degrees. • The gymnast grasps the 1/2-inch dowel with an overhand grip and tips of his thumbs touching. • The gymnast is asked to maximally flex his shoulders while maintaining his wrists in a neutral position, elbows extended and his nose and chin in contact with the floor. • The wooden dowel must be kept parallel to the floor. • Once the gymnast has raised his arms to their maximum height, the distance from the dowel, where his thumbs are touching, to the floor is measured and recorded to the nearest ½ centimeter using a rigid meter stick. • The gymnast must hold this position long enough to record the measurement. ➢ The raw test score is calculated by dividing the dowel height attained by the length of the athlete's arm

<table>
<tr><td rowspan="2">Splits Tests</td><td>

- Performance of the Splits Test involves left, right, and middle split measurement.
- Left/Right Split: Split testing will be carried out on the left and the right leg following the same procedure.
  - The left split is done in a position in which the left hip is flexed maximally and the right hip is extended maximally.
  - Before testing, the length of the gymnast's dominant leg is measured from the anterior superior iliac spine to a point on the anterior surface of the ankle in between the lateral and medial malleolus.
  - During both left and right splits testing, the gymnast places the anterior aspect of his trailing leg's tibia up against a wall in a vertical position to maintain the hip and pelvis in a neutral position.
  - He is then instructed to slide his lead foot out into a split position.
  - His back must be in a vertical position and hips and shoulders must be square or parallel to the wall. Please note that the alignment of the individual in the photograph is less than optimal due to limitations in his muscle length.
  - The gymnast is allowed to use paralettes on the left and right for support and to help maintain the proper test position. This position ensures the pelvis is in a standardized neutral position.
  - The measurement is taken from the ischial tuberosity to the floor.
  - A rigid centimeter ruler is held against the gymnast's sacrum to measure the distance between the ischial tuberosity and the floor to the nearest centimeter. If the gymnast is unable to perform the split completely to the floor, the measurement is referred to as a negative (-) centimeter measurement.
  - If the gymnast can achieve full contact during the split, an over-split should be performed.
    - The over-split involves an assistant passively flexing the lead hip while the gymnast maintains a neutral pelvis and extended knee position.
    - The hip is flexed until the gymnast says, "stop" or until the pelvis is lifted from the floor. The height from the posterior aspect of the heel to the floor is measured and recorded in cm.
    - The over-split measurement should be referred to as positive (+) centimeter
- Middle split testing involves the use of a straight line on the floor.
  - The gymnast is instructed to start the test in a standing position with his heels on the line and feet perpendicular to it.
  - He is then instructed to slide into a middle split position (both hips abducted maximally) keeping his legs parallel to or on the line.
  - The gymnast must lean forward and place his chest on the ground in order to obtain the lowest split position.
  - Once the correct testing position has been obtained, a measurement is taken from the ischial tuberosity to the floor.
  - If a gymnast is in full contact with the floor during correct performance of the middle split, an over split may be carried out and measured in the same manner described for the left and right splits.
  - The gymnast's dominant lower extremity will be used for over-split measurements.
  - The positive or negative angles calculated from the left, right and middle are then added to give a final split score.
- ➤ The raw test score will be determined by dividing left, right and middle split measurements (negative value) or the heel height in the case of an oversplit (positive value) measurement by the leg length and adding the values.

</td><td>

</td></tr>
</table>

Agility Test	• Two 6-inch cones are placed diagonally at the corners of a 12m x 12m gymnastics competition floor. • The gymnast starts standing in one corner of the floor in front of the cone with his feet together as if she were preparing for a tumbling pass. • When ready, the gymnast is instructed to sprint across the diagonal length of the floor, decelerate, touch the 6-inch cone and then turn around and repeat the run for a total of five passes ending in the corner opposite from where she started. • Timing starts as soon as the gymnast lifts a foot from the standing position. • Timing is stopped when any part of the gymnast's torso crosses over the finish line, which is an imaginary vertical plane from the corner of the floor. ➢ The raw test score is time recorded with a stopwatch to the nearest hundredth of a second.	

Handstand Test	• The gymnast is instructed to start the handstand on a set of parallel bars space 1.5 feet apart.
	    ○ Gymnasts are allowed their choice of lower extremity position while in the handstand.
	• Timing is to begin when the participant's feet pass above the bars
	• Timing is ended when any part of the gymnast's body (other than the hands) touched the bars or touched the floor.
	    ○ Timing is also stopped if either of the gymnast's hands moved from their original placement.
	• The participant should be given two trials for this test and his longest handstand hold should be used.
	
	➢ The raw test score is handstand time recorded with a stopwatch to the nearest one hundredth of a second.	

Score Sheet

Subject ID _____ **Level**_____ **Date** _____
*Any physical symptoms must be reported to the coach or test administrator and be documented

Arm length (Acromion process to wooden rod) _____cm
Leg Length (cm) L_____ R_____

1. **Hanging Pikes Test:** Testing muscular strength and endurance
   TEST SCORE /10_____
   a. Number of pikes achieved to touch the bar
   i. Number of completed Pikes _____
   <u>1-10 Score:</u> (0-3 = 0 pts, 4-9=1 pt, 10-13=2 pts, 14-17=3 pts, 18-21=4 pts, 22-25 =5 pts, 26-29 = 6 pts, 30-33=7 pts, 34-37=8 pts, 38-41.1 = 9 pts, >41 =10 pts)
   Symptoms and comments*

2. **Rings Hold Test:** Testing muscular strength and endurance
   TEST SCORE /10 _____
   a. Distance from the last 5 second hold to the axilla (starting mark) _____
   b. Score = (distance from last hold) / (arm length) _____
   <u>0-10 Score:</u> 0.1845 = 0 pts, 0.1845-0.2576 = 1 pts, 0.2577-0.3308 =2 pts, 0.3309-0.4040 = 3 pts, 0.4041-0.4772 = 4 pts, 0.4773-0.5504 = 5 pts, 0.5505-0.6236 = 6 pts, 0.6237-0.6968 = 7 pts, 0.6969-0.7700 = 8 pts, 0.7701-0.8433 = 9 pts, > 0.8434 = 10 pts
   Symptoms and comments*

3. **Vertical Jump Test:** Testing power
   TEST SCORE /10 _____
   a. Difference in the distance between static stand and reach height and maximal height achieved with a vertical counter movement jump.
   i. Jump height in cm _____
   <u>0-10 Score:</u> (<. 21cm=0 pts, 21.1-26cm=1 pts, 26.1-31cm=2 pts, 31.1-36cm=3 pts, 36.1-41cm=4 pts, 41.1-46cm=5 pts, 46.1-51cm=6 pts, 51.1-56cm=7 pts, 56.1-61cm=8 pts, 61.1-66cm=9 pts, >66.1cm=10 pts)
   Symptoms and comments*

4. **Shoulder Flexibility Test:** Testing Flexibility
   TEST SCORE /10 _____
   a. Distance From Floor _____cm, Distance from floor/arm length_____
   <u>0-10 Score:</u> (<0.1915= 0pts, .0192-0.3035 = 1 pts, 0.3036-0.4155 = 2 pts, 0.4156-0.5275 = 3 pts, 0.5276-0.6395 = 4 pts, 0.6396-0.7515 = 5 pts, 0.7516-0.8635= 6 pts, 0.8636-0.9755 = 7 pts, 0.9756-1.0875 = 8 pts, 1.0876-1.1995=9 pts, >1.1996=10 pts)

   Symptoms and comments*

a. Number of completed handstand push-ups _____
   0-10 Score: (0=0 pts, 1-2=1 pts, 3-5=2 pts, 6-8=3 pts, 9-11=4 pts, 12-14=5 pts, 15-17=6 pts, 18-20=7 pts, 21-23=8 pts, 24-26=9 pts, 27 > =10 pts)
   Symptoms and comments*

6. **Agility Test:** Testing speed, endurance and agility
                                                          TEST SCORE /10 _____
   a. Time _____
      0-10 Score: (>24.24 seconds = 0 pts, 24.23-23.33 seconds =1 pts, 23.32-22.41 seconds = 2 pts, 22.40-21.50 seconds = 3 pts, 21.49-20.58 seconds =4 pts, 20.57-19.66 seconds =5 pts, 19.65-18.78 seconds =6 pts, 18.77-17.83 seconds =7 pts, 17.82-19.92 seconds =8 pts, 19.91-16.00 seconds =9 pts, <15.99 seconds =10 pts)
      Symptoms and comments*

7. **Star Excursion Balance Test:** Testing balance
                                                          TEST SCORE /10 _____
   a. Reach Distances (cm)   0 degrees   _____   180 degrees   _____
                              45 degrees   _____   225 degrees   _____
                              90 degrees   _____   270 degrees   _____
                              135 degrees _____   315 degrees   _____
      Raw Score: (Total Reach distances / leg length) X 100 = _____
      0-10 Score: (<558= 0pts, 559-594 = 1 pts, 595-630 = 2 pts, 631-665 = 3 pts, 666-700 = 4 pts, 701-735 = 5 pts, 736-769= 6 pts, 770-805 = 7 pts, 806-839 = 8 pts, 840-875=9 pts, >876=10 pts)
      Symptoms and comments*

8. **Handstand Hold Test:** Testing Muscular endurance and inverted balance
                                                          TEST SCORE /10 _____
   a. Best time with 2 attempts
      i.   Time held trial #1 _____ Time held trial #2 _____
      0-10 Score: (0-1.99 seconds=0 pts, 2-7.36 seconds =1 pts, 7.37-19.82 seconds=2 pts, 19.83-32.28 seconds=3 pts, 32.29-44.24 seconds=4 pts, 44.25-57.20 seconds=5 pts, 57.21-69.66 seconds=6 pts, 69.67-82.12 seconds=7 pts, 82.13-94.58 seconds=8 pts, 94.59-107.04 seconds=9 pts, >107.04 seconds=10 pts)
      Symptoms and comments*

9. **Overgrip Pull-ups Test:** Testing Muscular strength and endurance
                                                          TEST SCORE /10 _____
   a. Number of completed Chin-ups _____
      0-10 Score: (0-1=0 pts, 2-3=1 pts, 4-5=2 pts, 6-7=3 pts, 8-9=4 pts, 10-11=5 pts, 12-13=6 pts, 14-15=7 pts, 16-17=8 pts, 18-19=9 pts, >20=10 pts)
      Symptoms and comments*

10. **Splits Test**: Testing Flexibility

TEST SCORE /10 _____

a. L split _____cm, R split _____cm, Middle split _____cm

("+"=standard split, "-" = over-split)

0-10 Score: (Sum of all 3 raw scores/leg length) >1.2275= 0 pts, 1.0-1.2274 = 1 pts, 0.849-1.038 =2 pts, 0.661-0.8491 = 3 pts, 0.4709-0.66 = 4, 0.2817-0.4708 = 5 pts, 0.0924-0.2816 = 6 pts, 0.0923-(-)0.0968 = 7 pts, (-)0.969-(-)0.2860 = 8 pts, (-)0.2861-(-)0.4752= 9 pts, < (-)0.4753 = 10 pts

Symptoms and comments*

TOTAL MGFMT TEST SCORE /100_____